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(54) **Transparent display with diffuser-backed microtextured illuminating device and method of manufacture therefor**

(57) A substantially planar illuminating device, a visual display and a method of manufacture therefor. The illuminating device includes: (1) a light source (210) and (2) a transparent substrate (220) having a pair of substantially parallel major surfaces (230, 240) and an entry point (250) for accepting light from the light source, the substrate functioning as a guide for the light, one of the pair of surfaces textured with a plurality of microelements (260) for scattering the light from the substrate, the microelements having a side wall with a side wall area, the side wall area being a function of a distance of the microelements from the entry point to enhance a uniformity of the scattering of the light over an area of the pair of surfaces.

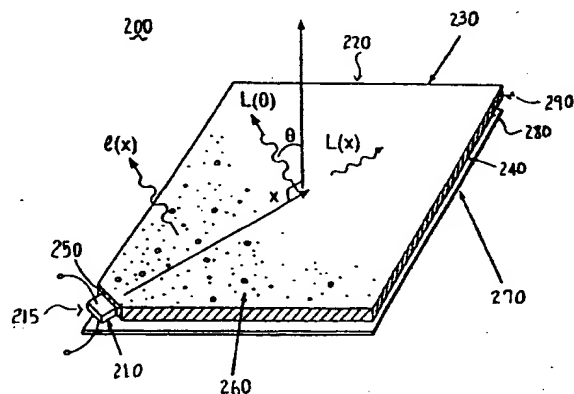


FIGURE 2

## Description

### TECHNICAL FIELD OF THE INVENTION

The present invention is directed, in general, to illuminating devices and, more specifically, to an illuminating device useful for illuminating transparent displays, such as liquid crystal displays ("LCDs").

### BACKGROUND OF THE INVENTION

The combination of microelectronic circuits and low power transparent displays, such as liquid crystal displays ("LCDs"), has led to a wide variety of portable electronic products. "Transparent displays," as used herein, refers to visual display devices wherein either the visual message portion of the display or the background portion of the display is transparent or translucent. These products range from electronic watches to hand-held television receivers and laptop computers. Low power consumption is a critical requirement for each of these products.

Despite their considerable utility in conjunction with integrated circuits, LCDs have a number of shortcomings. In typical LCDs, the activated portion (perhaps representing a visual message) is darkened and the inactivated portion (perhaps representing a background for the visual message) is lightened by contrast. One shortcoming of LCDs is that the contrast between the activated and inactivated portions is relatively low due to reflections off the LCD surface, making the LCD hard to read. The contrast can be increased by backlighting the LCD, thereby producing a sharp contrast between the portions of the LCD darkened by activation and the light shining through the transparent, inactive portions. Currently, electroluminescence ("EL") devices provide the highest spatial and angular backlighting uniformity. EL devices, however, require a special, relatively high-voltage inverter and suffer from a relatively short lifetime. All conventional backlighting arrangements, including EL devices, are inefficient. Even in so complex an electronic structure as a portable computer, the power used in backlighting is responsible for a major portion of total battery drain.

U.S. Patent Number 5,245,454, issued on September 14, 1993, to Blonder, entitled "LCD Display With Microtextured Back Reflector And Method For Making Same," commonly assigned with the present invention and incorporated herein by reference, discloses a microtextured reflector having dispersion characteristics of enhanced uniformity and a display device that can be read over an enhanced range of viewing angles. Specifically, a reflector comprises a base plane having a microtextured surface comprising a pattern of microelements having maximum lateral dimensions less than 125 microns and smooth, continuous, mold-formed surfaces arising from the base plane. A preferred reflecting surface is composed of closely-packed, smooth-surfaced spherical segments having diameters of 25

microns and altitudes of 4 microns.

U.S. Patent Number 5,349,503, issued on September 20, 1994, to Blonder, et al., entitled "Illuminated Transparent Display With Microtextured Back Reflector," commonly assigned with the present invention and incorporated herein by reference, discloses a particularly efficient illuminating device for a transparent display comprising a microtextured reflecting surface formed on a major surface of a transparent substrate and a light source for directing light into the transparent substrate approximately parallel to the major surface. Preferably, the substrate has two major surfaces separated by a thickness in the range of 0.5 mm to 2.0 mm so that the substrate behaves as a light guide. A substantial portion of the light passing into the substrate undergoes total internal reflection until it hits a microelement and is reflected out of the substrate. The result is an efficient illuminating device particularly useful for backlighting LCDs or other transparent displays.

Accordingly, what is needed in the art is an illuminating device for a transparent display that provides light of acceptable spatial and angular uniformity with minimal power consumption and a method of manufacture therefor.

### SUMMARY OF THE INVENTION

To address the above-discussed need in the prior art, the present invention provides a substantially planar illuminating device, a visual display and a method of manufacture therefor. The illuminating device includes: (1) a light source and (2) a transparent substrate having a pair of substantially parallel major surfaces and an entry point for accepting light from the light source, the substrate functioning as a guide for the light, one of the pair of surfaces textured with a plurality of microelements for scattering the light from the substrate, the microelements having a side wall with a side wall area, the side wall area being a function of a distance of the microelements from the entry point to enhance a uniformity of the scattering of the light over an area of the pair of surfaces.

The present invention recognizes that illumination within the substrate varies as a function of the distance from the light source and compensates for that variation by decreasing the side wall area of the microelements that are nearer the light source, and increasing the side wall area of those that are farther away. In effect, the side wall area determines the amount of light scattered by each microelement.

The substrate may be quartz, glass, plastic or any other relatively transparent material capable of being employed as a light guide and capable of being textured appropriately with the microelements.

In a preferred embodiment of the present invention, the entry point is located at a corner of the substrate. It has been found that the corner is an optimal placement for the entry point. However other entry point locations are within the broad scope of the present invention.

In a preferred embodiment of the present invention, the microelements are substantially frustoconical indentations in the one of the pair of surfaces. In a manner to be shown, frustoconical indentations are optimal in that they effectively scatter light produced by the light source without unduly scattering ambient light that may enter via the adjacent transparent display.

In a preferred embodiment of the present invention, the device further comprises a layer of diffusing material located over the one of the pair of surfaces. In a more preferred embodiment, the diffusing material is selected from the group consisting of: (1) a metallized polycrystalline diamond film, (2) a spun bonded olefin and (3) paper. It has been found that diffusing the light yields increased uniformity of light compared with reflecting the light. However, reflecting or absorbing light is within the broad scope of the present invention.

In a preferred embodiment of the present invention, the device further comprises a layer of reflective material over minor surfaces of the substrate to reflect the light within the substrate.

In a preferred embodiment of the present invention, the light source is a surface-emitting light emitting diode ("LED"). Other light sources, such as incandescent or fluorescent sources or EL devices are within the broad scope of the invention.

In a preferred embodiment of the present invention, the pair of major surfaces are spaced apart by a thickness of about 0.5 mm to about 2.0 mm. However, the broad scope of the present invention contemplates substrates of any thickness or lateral dimension.

The foregoing has outlined, rather broadly, preferred and alternative features of the present invention so that those skilled in the art may better understand the detailed description of the invention that follows. Additional features of the invention will be described hereinafter that form the subject of the claims of the invention. Those skilled in the art should appreciate that they can readily use the disclosed conception and specific embodiment as a basis for designing or modifying other structures for carrying out the same purposes of the present invention. Those skilled in the art should also realize that such equivalent constructions do not depart from the spirit and scope of the invention in its broadest form.

### **BRIEF DESCRIPTION OF THE DRAWINGS**

For a more complete understanding of the present invention, reference is now made to the following descriptions taken in conjunction with the accompanying drawings, in which:

FIGURE 1 illustrates an isometric view of a portable computer providing an environment in which the present invention operates;

FIGURE 2 illustrates an isometric view of an illuminating device constructed according to the principles of the present invention;

FIGURE 3 illustrates an isometric view of a portion of the illuminating device of FIGURE 2;

FIGURES 4A, 4B and 4C illustrate cross-sectional views of substantially frustoconical indentations having side walls with a side wall area;

FIGURE 5 illustrates a plot of surface luminance as a function of light source distance for microelements of uniform and nonuniform depths;

FIGURE 6 illustrates a log-log plot of in-plane luminance and surface luminance as a function of light source distance;

FIGURE 7 illustrates a plot of luminance as a function of viewing angle;

FIGURE 8 illustrates a plot of reflection brightness as a function of diffuser material; and

FIGURES 9A and 9B illustrate flow diagrams of representative methods of manufacturing a substrate for a microtextured illuminating device of the present invention.

### **DETAILED DESCRIPTION**

Referring initially to FIGURE 1, illustrated is an isometric view of a portable computer, generally designated 100, providing an environment in which the present invention operates. The portable computer 100 comprises a lower half 110 and an upper half 120. The lower half 110 comprises an outer shell or chassis 111 that contains various, compactly-arranged electronic components of the portable computer 100 and a keyboard 112 allowing a user to transmit information to the portable computer 100.

The upper half 120 contains a visual display or monitor 121 allowing the portable computer 100 to transmit information to the user. The visual display or monitor 121 preferably includes a transparent display device capable of conveying a visual message by varying a relative contrast of a visual message portion of the display device and a background portion of the display device. The illuminating device of the present invention is preferably located behind the display device and provides light for the display device at least under conditions of low or no ambient light. The portable computer 100 is presented for illustrative purposes only and other applications (for the illuminating device) including, without limitation, high efficiency large viewing angle sub-threshold lighting such as a nightlight, are well within the scope of the present invention.

The lower half 110 and the upper half 120 are hinged together so as to allow the lower half 110 and the upper half 120 to rotate relative to each other. This allows the portable computer 100 to assume a closed, storage position wherein the upper and lower halves 110, 120 shield the keyboard 112 and the monitor 121 from damage and wherein the portable computer 100 can be conveniently stored. The portable computer 100 can also assume (as shown) an open, operating position wherein the keyboard 112 and the monitor 121 are exposed to a user for communication therewith.

Turning now to FIGURE 2, illustrated is an isometric view of an illuminating device 200 constructed according to the principles of the present invention. The illuminating device 200 includes a light source 210 such as a LED (e.g., an amber AlInGaP LED manufactured by Hewlett Packard) mounted in a corner 215. While the light source is demonstrated as a LED, other light sources, such as, without limitation, multicolor LEDs, incandescent sources, fluorescent sources or EL devices, are within the broad scope of the invention.

The illuminating device 200 also includes a transparent substrate 220 having a pair of substantially parallel major surfaces 230, 240 (spaced apart, for illustrative purposes only, by a thickness of about 0.5 mm to about 2.0 mm) and an entry point (generally designated 250) for accepting light from the light source 210. The substrate 220 functions as a guide for the light. The major surface 230 is textured with a plurality of microelements (collectively designated 260) for scattering the light from the substrate 220 to, ultimately, a display device (see FIGURE 1). The major surface 230 may alternatively emit a modulated light signal as a wireless communication link to a remotely located receiver and display device. The substrate 220 may be quartz, glass, plastic or any other relatively transparent material capable of being employed as a light guide and capable of being textured appropriately with the microelements 260. The microelements 260 comprise a side wall (see FIGURE 3) having a side wall area; the side wall area is a function of a distance of the microelements 260 from the entry point 250 to enhance a uniformity of the scattering of the light over an area of the pair of surfaces 230, 240.

The present invention recognizes that illumination within the substrate 220 varies as a function of the distance from the light source 210 and compensates for that variation by decreasing the side wall area of the microelements 260 that are nearer the light source 210, and increasing the side wall area of the microelements 260 that are farther away from the light source 210. In effect, the side wall area determines the amount of light scattered by each microelement 260.

In the illustrated embodiment, the entry point 250 is located at the corner 215 of the substrate 220. It has been found that a corner of the substrate 220 is an optimal placement for the entry point 250. However, other entry point locations, including, without limitation, an imbedded light source in the substrate 220 to thereby isotropically illuminate the substrate 220 and illuminating device 200, are within the broad scope of the present invention.

The illuminating device 200 further includes a diffuser 270 comprising a layer of diffusing material located over the major surface 240 to reflect ambient light in a reflector mode of operation. The diffusing material is generally selected from a group consisting of a metallized polycrystalline diamond film, spun bonded olefin and paper. The diffuser 270 provides increased uniformity of light compared with reflecting the light.

However, reflecting or absorbing light is also within the broad scope of the present invention.

In the illustrated embodiment, the illuminating device 200 still further comprises a layer of reflective material (designated 280) over the minor surfaces (collectively designated 290) of the substrate 220 to reflect the light within the substrate 220 thereby further improving the uniformity around the minor edges 290 of the illuminating device 200.

The illuminating device 200 is, therefore, capable of operating in two separate modes of operation. In a passive, lighting ambient application or reflector mode of operation, a maximum transparency may be achieved by minimizing scattering through the substrate 220. Conversely, in an active, back illumination mode of operation, a maximum scattering of the photons throughout the substrate 220 improves contrast viewing. To optimize the two modes of operation, it is desirable to maximize the flat area in the substrate 220 (to facilitate transparency) for the reflector mode of operation, and to maximize right angle scattering from the light source 260 for the back illumination mode of operation. The present invention takes into account the above referenced criteria and therein provides an illuminating device that facilitates optimal viewing proficiency in either mode of operation.

A representative method of manufacturing the illuminating device 200 will hereinafter be described. First, an entry point 250 is formed on the corner 215 of the substrate 220 and the light source 210 is coupled thereto; the entry point 250 is capable of accepting light from the light source 210 and the substrate 220 functions as a guide for the light. Second, the major surface 230 is etched with the microelements 260 (e.g., frustoconical indentations) for scattering the light from the substrate 220 (see the description associated with FIGURES 9A, 9B for an explanation of representative methods of manufacturing the substrate 220 and microelements 260 etched thereon). Again, the microelements 260 have a side wall with a side wall area; the side wall area being a function of a distance of the microelements from the entry point 250 to enhance a uniformity of the scattering of the light over an area of the major surfaces 230, 240. Third, the layer of reflective material 280 may be formed over the minor surfaces 290 of the substrate 220 to reflect the light within the substrate 220 thereby further improving the uniformity around the minor surfaces 290 of the illuminating device 200. For instance, the minor surfaces 290 of the substrate 220 may be flame polished and metallized with aluminum. Finally, the diffuser 270 is located over the major surface 240.

The illustrated embodiment also demonstrates a surface luminance [designated  $I(x)$ ] and an in-plane luminance [designated  $L(x)$ ] as a function of a distance "x" from the light source 210. The illustrated embodiment further demonstrates a viewing angle " $\theta$ " and a viewing angle luminance [designated  $L(\theta)$ ]. The illustrated embodiment, therefore, demonstrates that the

substrate 220 acts as light guide and the microelements scatter the light to achieve uniform luminance at a wide array of viewing angles.

Turning now to FIGURE 3, illustrated is an isometric view of a portion of the illuminating device of FIGURE 2. More specifically, the illustrated embodiment presents a scanning electron microscopy ("SEM") micrograph of an array of scattering centers (collectively designated 310) of the microelements 260 textured into the major surface 230 of the substrate 220. As previously mentioned, the microelements 260 comprise a side wall 320 having a side wall area; the side wall area is a function of a distance of the microelements 260 from the entry point (see FIGURE 2) to enhance a uniformity of the scattering of the light over an area of the substrate 220. Thus, the illumination within the substrate 220 varies as a function of the distance from the light source (see FIGURE 2) and compensates for that variation by decreasing the side wall area of the microelements 260 that are nearer the light source, and increasing the side wall area of the microelements 260 that are farther away from the light source.

Turning now to FIGURES 4A, 4B and 4C, illustrated are cross-sectional views of substantially frustoconical indentations 410, 420, 430 having side walls 440, 450, 460, respectively, with varying side wall areas. The substantially frustoconical indentations 410, 420, 430 function as microelements in the surfaces of the substrate as indicated in FIGURES 2 and 3. The frustoconical indentations 410, 420, 430 are optimal in that they effectively scatter light produced by a light source without unduly scattering ambient light that may enter via an adjacent transparent display (see FIGURES 1 and 2). Again, the side wall area is smaller for the frustoconical indentations 410, 420, 430 that are nearer a light source, and the side wall area is larger for the frustoconical indentations 410, 420, 430 that are farther away from the light source.

Turning now to FIGURE 5, illustrated is a plot 500 of surface luminance  $I(x)$  as a function of light source distance for microelements of uniform depth (designated by dotted line 510) and microelements of nonuniform depth (designated by solid line 520). A substrate employing microelements of uniform depth pertains to a condition where the microelements are textured at a uniform depth within the substrate forming an illuminating device. A substrate employing microelements of nonuniform depth pertains to a condition where the microelements are textured at varying depths within the substrate forming an illuminating device. The plot 500 illustrates the surface luminance  $I(x)$  of an illuminating device analogous to the illuminating device described with respect to FIGURE 2.

In short, the illuminating device includes a light source mounted in a corner of a transparent substrate having a pair of substantially parallel major surfaces spaced apart by a thickness of about 1.7 mm. The substrate functions as a guide for the light. A major surface of the substrate is textured with a plurality of microele-

ments at uniform and nonuniform depths. The entry point for the light is located at the corner (via the light source) of the substrate. The illuminating device further includes a diffuser comprising a layer of white tyvek paper located over a major surface to reflect ambient light in a reflector mode of operation.

The plot 500 demonstrates that for both the microelements at the uniform and nonuniform depths 510, 520 about a ten-fold reduction in surface luminance  $I(x)$  occurs from the source end A (i.e., light source end) to the far end C of the illuminating device. Generally, the distance between the source end A and the far end C is about 10 cm. The luminance, therefore, drops by approximately a factor of 2 for every 2 cms farther away from the source end A. Additionally, the plot 500 demonstrates that the microelements of nonuniform depth 520 realize an improved luminance  $I(x)$  over the microelements of uniform depth 510 over the entire range of distance from the source to far end A, C of the illuminating device with the largest disparity revealed at about 5 - 5.5 cm from the source end at a point B. Finally, the plot 500 displays higher intensity light at the edges (designated 530, 540) of the illuminating device. The light at either end is attributed to stray light 530 from the source end A and leakage light 540 at the far end C. However, the stray and leakage light 530, 540 may be shielded by adding flame polished and metallized aluminum edges or minor surfaces about the pair major surfaces of the substrate to form a frame housing about the substrate thereby creating a less distracting background for the illuminating device.

Turning now to FIGURE 6, illustrated is a log-log plot 600 of in-plane luminance  $L(x)$  (designated by line 610) and surface luminance  $I(x)$  (designated by line 620) as a function of light source distance. The log-log plot 600 illustrates the in-plane luminance  $L(x)$  and surface luminance  $I(x)$  of an illuminating device analogous to the illuminating device described with respect to FIGURE 2. Again, the illuminating device includes a light source mounted in a corner of a transparent substrate having a pair of substantially parallel major surfaces spaced apart by a thickness of about 1.7 mm. The substrate functions as a guide for the light. A major surface of the substrate is textured with a plurality of microelements of uniform and nonuniform depth. The entry point for the light is located at the corner (via the light source) of the substrate. The illuminating device further includes a diffuser comprising a layer of white tyvek paper located over a major surface to reflect ambient light in a reflector mode of operation.

The log-log plot 600 demonstrates that, for both the in-plane luminance  $L(x)$  610 and surface luminance  $I(x)$  620, the luminance may be approximated by a  $1/x$  dependence, where  $x$  corresponds to a distance from a source end (i.e., light source end) of the illuminating device. Generally, the distance between the source end and a far end of the illuminating device is about 100 mm. As previously mentioned, there is about a two order of magnitude reduction in luminance from the source to far

end of the illuminating device.

The log-log plot 600 also illustrates that about 15% of the light (*i.e.*,  $I(x)/L(x) = .20$ ) is redirected thereby suggesting that the illuminating device is more efficient as a light guide than as a reflector of ambient light. A deeper or larger cross-sectional and faster textured microelement may therein improve the efficiency of the reflector. The relationship of luminance to distance away from the light source (denoted by  $1/x$ ) suggests that to compensate for the nonuniformity of the illuminating device brightness a surface cross-sectional area of the microelements should vary linearly as the distance from the light source varies. It is important to note that the ambient light considerations are significant because in the reflector mode of operation the ambient light passes through the substrate to the diffuser and, then, reflects back through the substrate to a viewer. A high transparency illuminating device provides a higher display contrast during the reflector mode of operation analogous to the back illumination mode of operation. By partitioning the functions of the light guide and reflector between the substrate and diffuser the performance of the illuminating device in either mode of operation is vastly improved.

Turning now to FIGURE 7, illustrated is a plot 700 of luminance  $I(x)$  (designated as line 710) as a function of viewing angle (denoted by  $\theta$ ). The viewing angle  $\theta$  is simply the angle a viewer is observing a display employing an illuminating device according to the principles of the present invention. Once again, the illuminating device includes a light source mounted in a corner of a transparent substrate having a pair of substantially parallel major surfaces spaced apart by a thickness of about 1.7 mm. The substrate functions as a guide for the light. A major surface of the substrate is textured with a plurality of microelements of uniform or nonuniform depth. The entry point for the light is located at the corner (via the light source) of the substrate. The illuminating device further includes a diffuser comprising a layer of white tyvek paper located over a major surface to reflect ambient light in a reflector mode of operation. The plot 700 illustrates a plurality of viewing angles  $\theta$ , for instance, at a point Z the viewer is observing the display at  $0^\circ$  or basically straight on center. The plot 700 demonstrates that, in accordance with the principles of the present invention, the luminance  $I(x)$  over a broad viewing angle  $\theta$  remains relatively equal thereby providing a significant improvement over prior art illuminating devices.

Turning now to FIGURE 8, illustrated is a plot 800 of reflection brightness as a function of diffuser material. As previously mentioned, the diffuser is located over a major surface of a substrate to reflect ambient light when an illuminating device is operating in a reflector mode of operation. The reflection brightness is demonstrated for a plurality of commercially available materials including background material for a conventional wrist-watch 810, tyvek paper 820, metallized poly-crystalline diamond film 830 and white note paper 840. The plot

800 demonstrates a broad band of reflection brightness is attainable depending on the designated diffuser material. The above referenced materials are presented for illustrative purposes only and other reflective materials capable of functioning as a diffuser are within the broad scope of the invention.

Turning now to FIGURES 9A and 9B, illustrated are flow diagrams of representative methods of manufacturing a substrate for a microtextured illuminating device of the present invention. Beginning with FIGURE 9A, demonstrated is a processing sequence 900 for the formation of a substrate miniscus. The process 900 commences by a Piranha-Clean ("P-Clean") of a wafer or substrate, such as, without limitation, a quartz wafer, in a clean step 905. Next, the substrate undergoes a photolithography process generally comprising the following steps. First, a photomask is designed encompassing a design for each layer of the substrate in a design step 910. Second, the substrate is coated with a light sensitive film that hardens when exposed to light shining through the photomask in a photomask step 915. Third, the substrate is exposed to a chemical bath in a flow/melt photoresist step 920. Fourth, the substrate undergoes a reactive ion etching process whereby microelements are etched into the substrate in an etching step 925. Finally, the photomask is removed in a remove step 930 and a formed substrate miniscus is created.

The shape of the microelements is a function of the viscosity and aspect ratio (*i.e.*, thickness/feature size) of the developed photoresist patterns in the photomask and the miniscus is formed by melting the photoresist pattern into the substrate. The shape of the microelements may be flattened by, for instance, terminating the etching process before the full photoresist pattern is consumed. Additionally, the side wall profile of the microelements may be varied by adjusting the selectivity of the etching process.

Turning now to FIGURE 9B, demonstrated is a process sequence 950 for generating a nonuniform profile in the substrate miniscus. The process 950 commences, again, by a Piranha-Clean ("P-Clean") of the wafer or substrate, such as, without limitation, a quartz wafer, in a clean step 955. Next, the substrate undergoes a photolithography process generally comprising the following steps. First, a photomask is designed encompassing a design for each layer of the substrate in a design step 960. Second, the substrate is coated with a light sensitive film that hardens when exposed to light shining through the photomask in a photomask step 965. Third, the substrate is exposed to a chemical bath in a flow/melt photoresist step 970. Fourth, the substrate is dipped into a buffered oxide etching ("BOE") solution under spatially controlled conditions whereby microelements are etched, at nonuniform depths, into the substrate in a dip etching step 975. Finally, the photomask is removed in a remove step 980 and a formed substrate miniscus is created.

The gradient may be programmed into the process



950 for specific designs and analogous methods may be employed in the reactive ion etching step 925 of the process 900 previously introduced. The features of the microelements may be varied in the process 950 by, for instance, locating opaque features on the photomask thereby resulting in a flat-top scattering center and linear side wall microelement. If a reverse tone feature (i.e., holes in the photomask) is employed, crater-like microelements, having a flat bottom and cylindrical side wall, result in a process similar in nature to isotropic etching. In general, the wet chemical etching is a more efficient process and requires less equipment thereby providing higher through-put at lower cost.

The above referenced processes 900, 950 can serve as the basis for preparing a master template by electroforming. The master template may then be employed to fabricate plastic piece parts either by molding or by embossing plastic sheets in rolls with the desired features. Additionally, a substrate may be employed without flame polishing and without metalizing the surfaces, including both the major and minor surfaces (see FIGURE 2), by optimizing the scattering center design of the microelements as described above. Significant cost reductions are available by providing an illuminating device without smoothing out or metalizing the minor surfaces or plastic piece parts during production. Therefore, the present invention provides an illuminating device that optimizes performance and reliability and at the same time reduces power consumption and manufacturing costs. Although the present invention has been described in detail, those skilled in the art should understand that they can make various changes, substitutions and alterations herein without departing from the spirit and scope of the invention in its broadest form.

## Claims

1. A substantially planar illuminating device, comprising:

a light source; and  
a transparent substrate having a pair of substantially parallel major surfaces and an entry point for accepting light from said light source, said substrate functioning as a guide for said light, one of said pair of surfaces textured with a plurality of microelements for scattering said light from said substrate, said microelements having a side wall with a side wall area, said side wall area being a function of a distance of said microelements from said entry point to enhance a uniformity of said scattering of said light over an area of said pair of surfaces.

2. A method of manufacturing a substantially planar illuminating device, comprising the steps of:

forming an entry point on a transparent sub-

strate having a pair of substantially parallel major surfaces, said entry point capable of accepting light from a light source, said substrate functioning as a guide for said light;

etching one of said pair of surfaces with a plurality of microelements for scattering said light from said substrate, said microelements having a side wall with a side wall area, said side wall area being a function of a distance of said microelements from said entry point to enhance a uniformity of said scattering of said light over an area of said pair of surfaces.

3. A visual display, comprising:

a substantially planar transparent display device for conveying a visual message by varying a relative contrast of a visual message portion of said display device and a background portion of said display device;

a substantially planar illuminating device aligned with said visual display device to provide light thereto, said illuminating device including:

a light source;

a transparent substrate having a pair of substantially parallel major surfaces and an entry point, located at a corner of said substrate, for accepting light from said light source, said substrate functioning as a guide for said light, one of said pair of surfaces textured with a plurality of frustoconical indentations for scattering said light from said substrate and to said display device, said frustoconical indentations having a side wall with a side wall area, said side wall area being a function of a distance of said frustoconical indentations from said entry point to enhance a uniformity of said scattering of said light over an area of said pair of surfaces;

a layer of reflective material over minor surfaces of said substrate to reflect said light within said substrate; and

a layer of diffusing material located over said one of said pair of surfaces.

4. The device as recited in Claim 1 or 2, wherein said entry point is located or formed at a corner of said substrate.

5. The device as recited in Claim 1, or 2, wherein said microelements are substantially frustoconical indentations formed in said one of said pair of surfaces.

6. The device as recited in Claim 1 or 2, wherein a layer of diffusing material is formed over said one of said pair of surfaces.

7. The device as recited in Claim 3 or 6, wherein said

diffusing material is selected from

a metallised polycrystalline diamond film,  
a spun bonded olefin, and  
paper.

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8. The device as recited in Claim 1 or 2, wherein a layer of reflective material is formed over minor surfaces of said substrate to reflect said light within said substrate.

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9. The device as recited in Claim 1, 2 or 3, wherein said light source is a surface-emitting light emitting diode (LED).

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10. The device as recited in Claim 1, 2 or 3, wherein said pair of major surfaces are spaced apart by a thickness of about 0.5mm to about 2.0mm.

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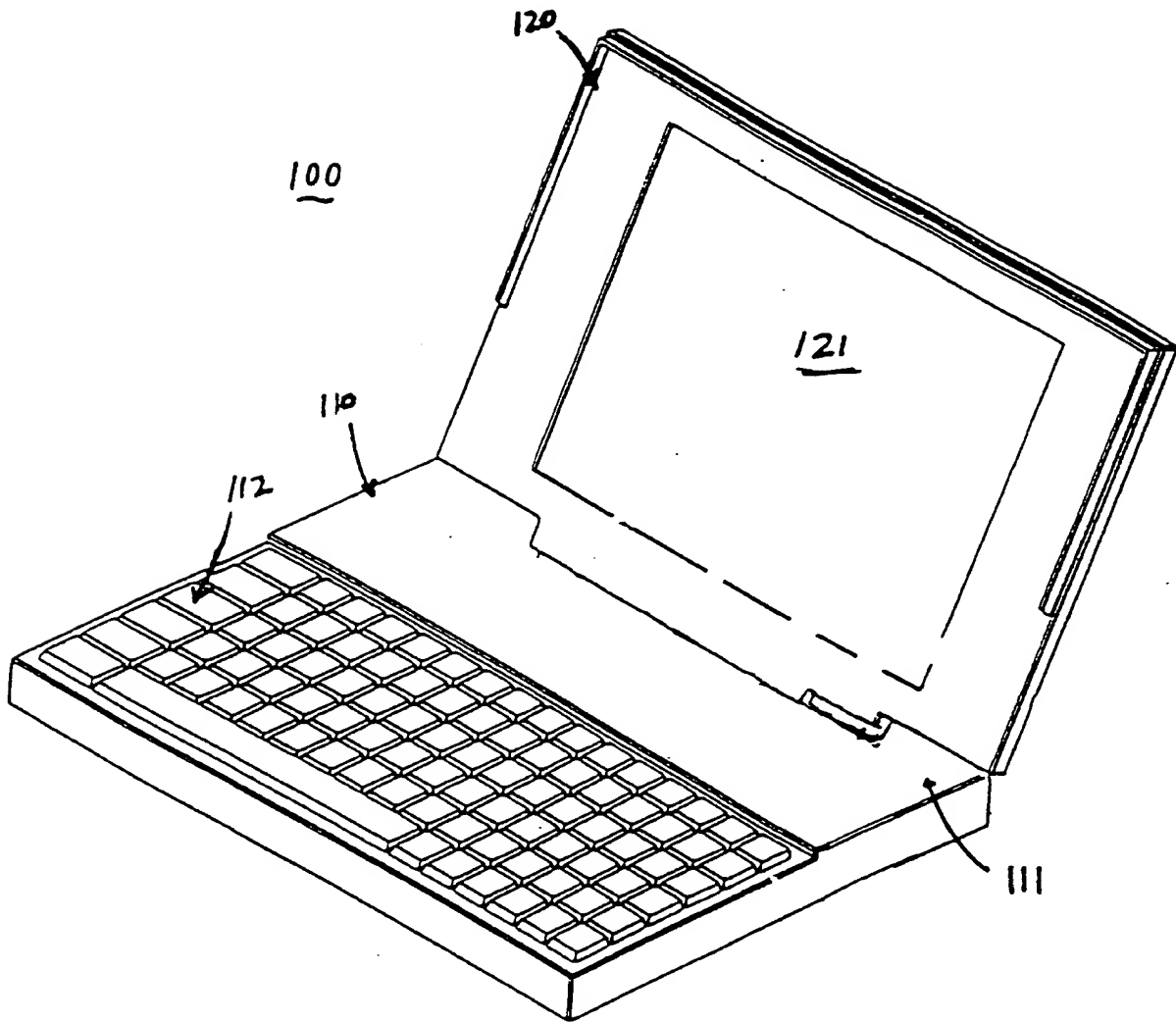


FIGURE 1

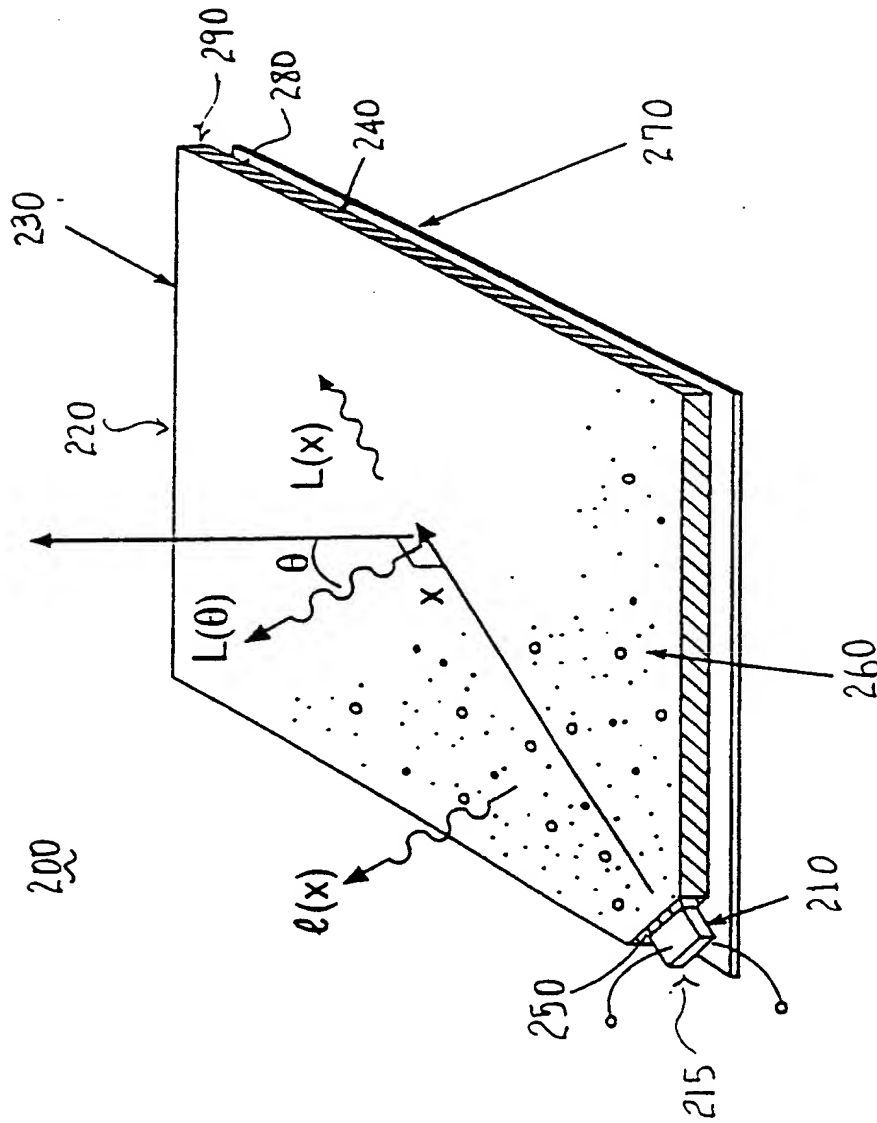


FIGURE 2

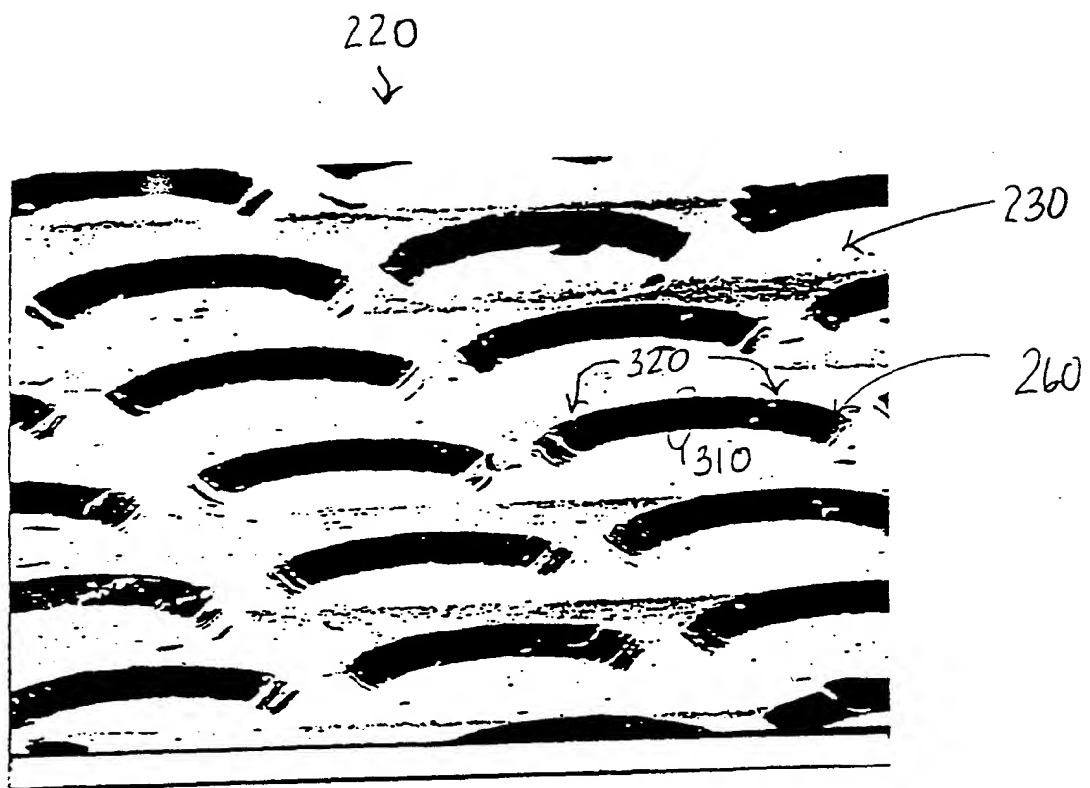


FIGURE 3

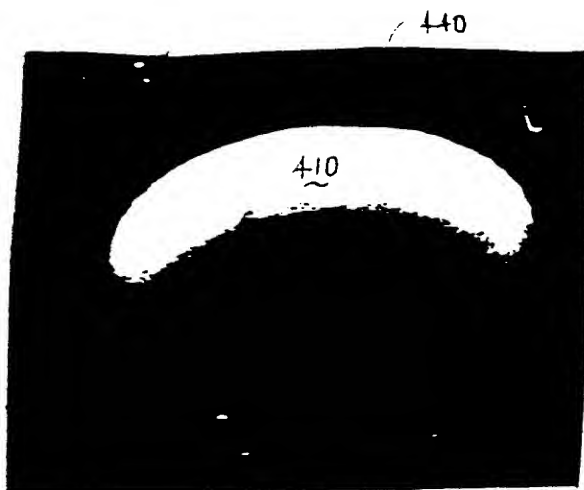


FIGURE 4A



FIGURE 4B

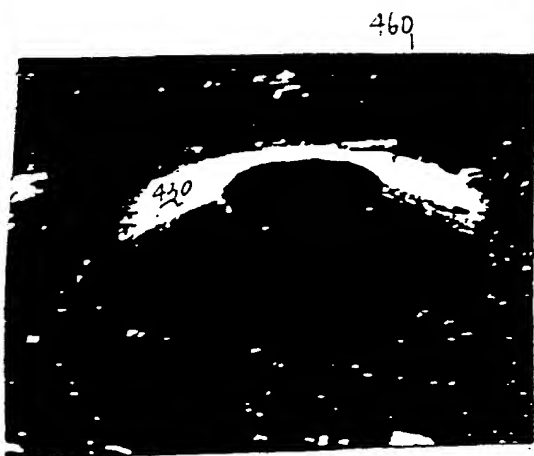


FIGURE 4C

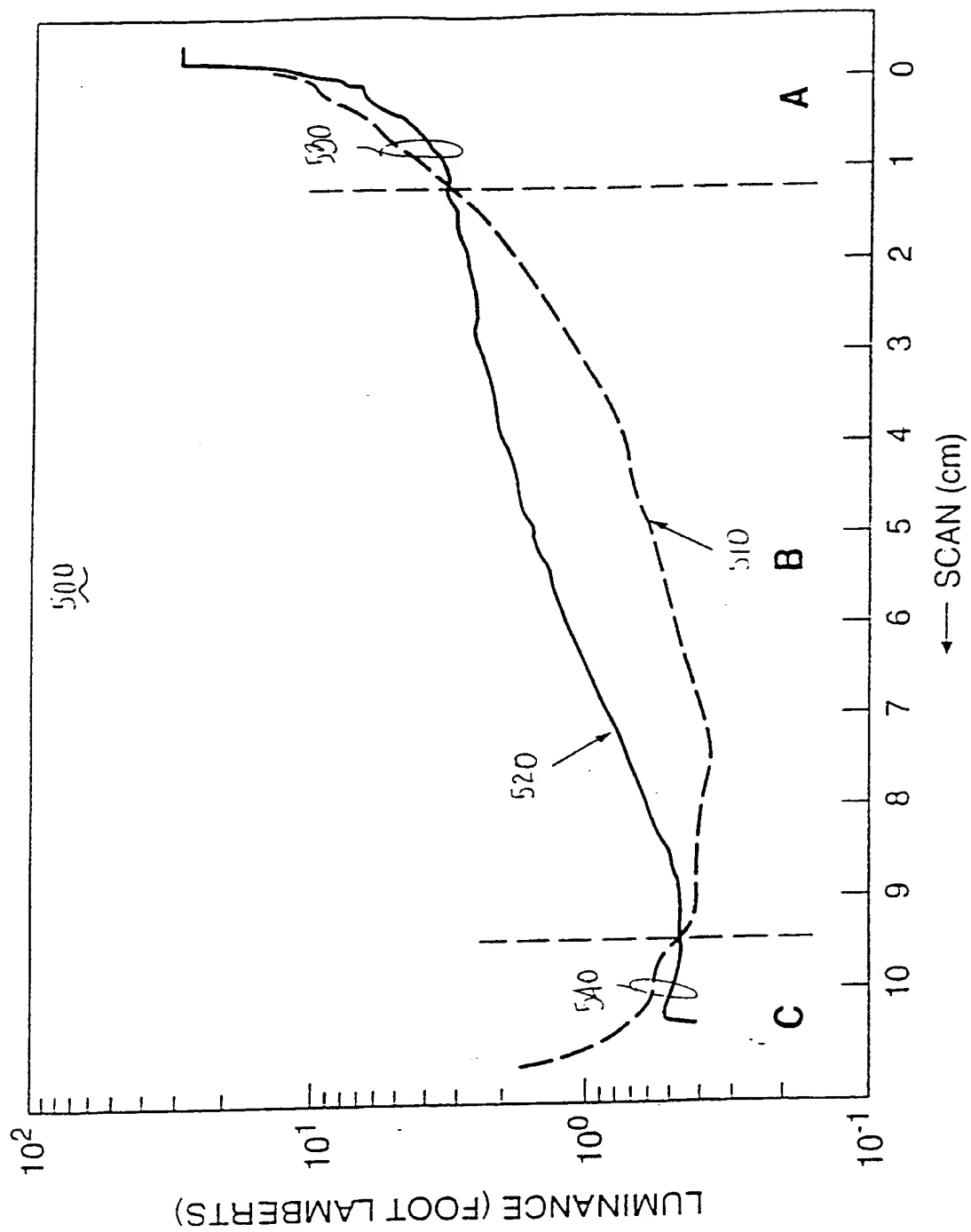


Figure 5

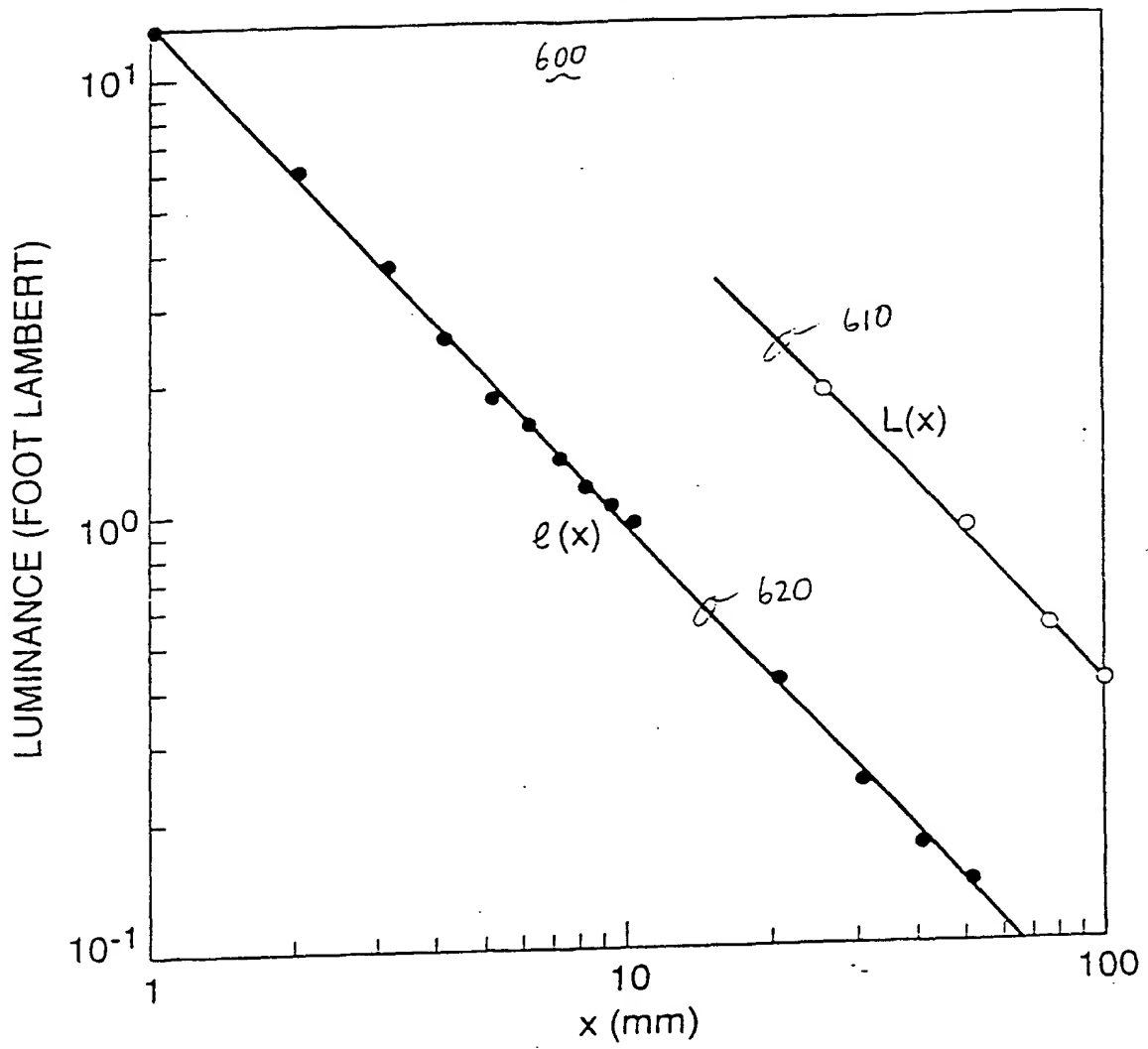


Figure 6

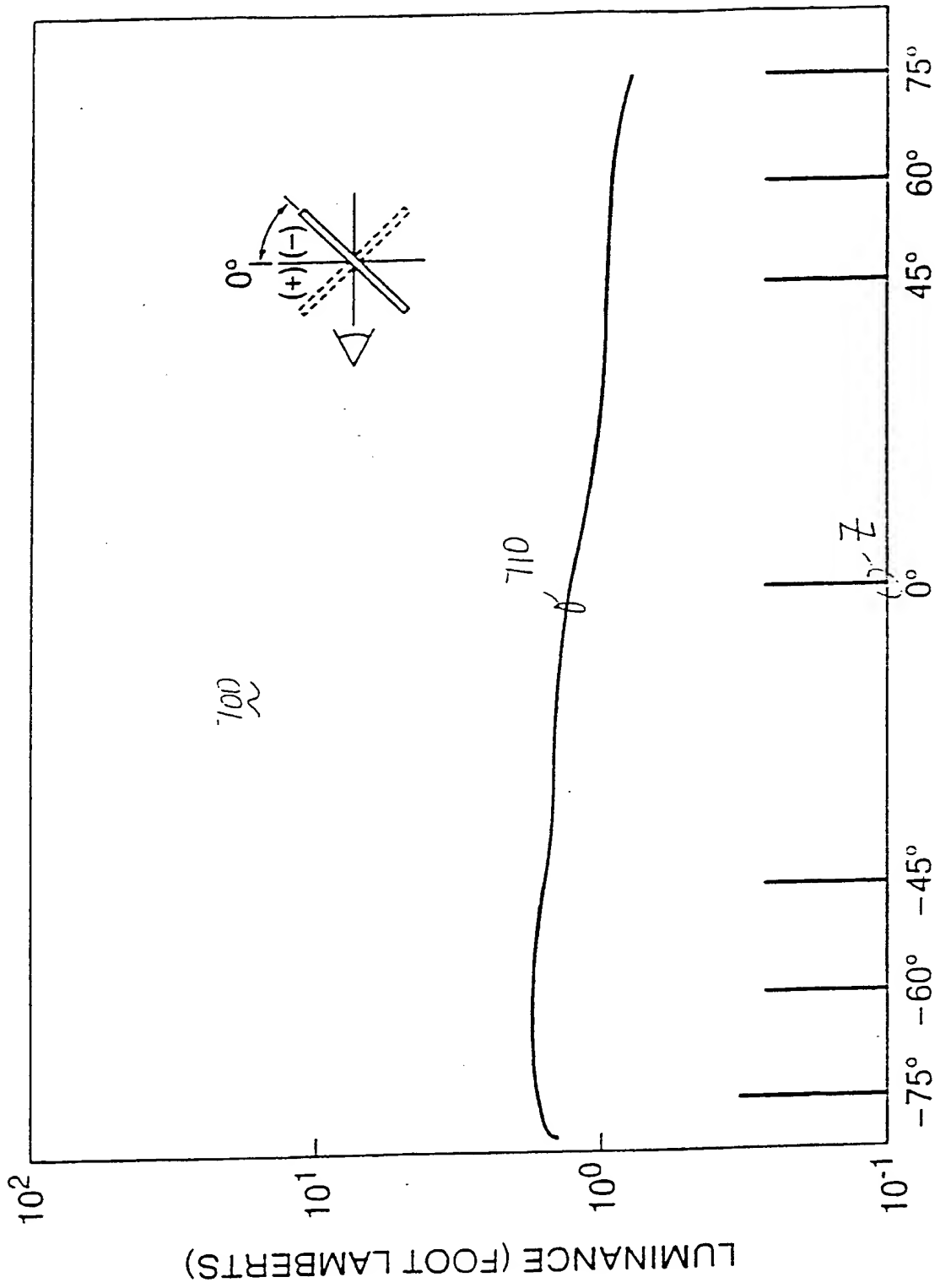


Figure 7



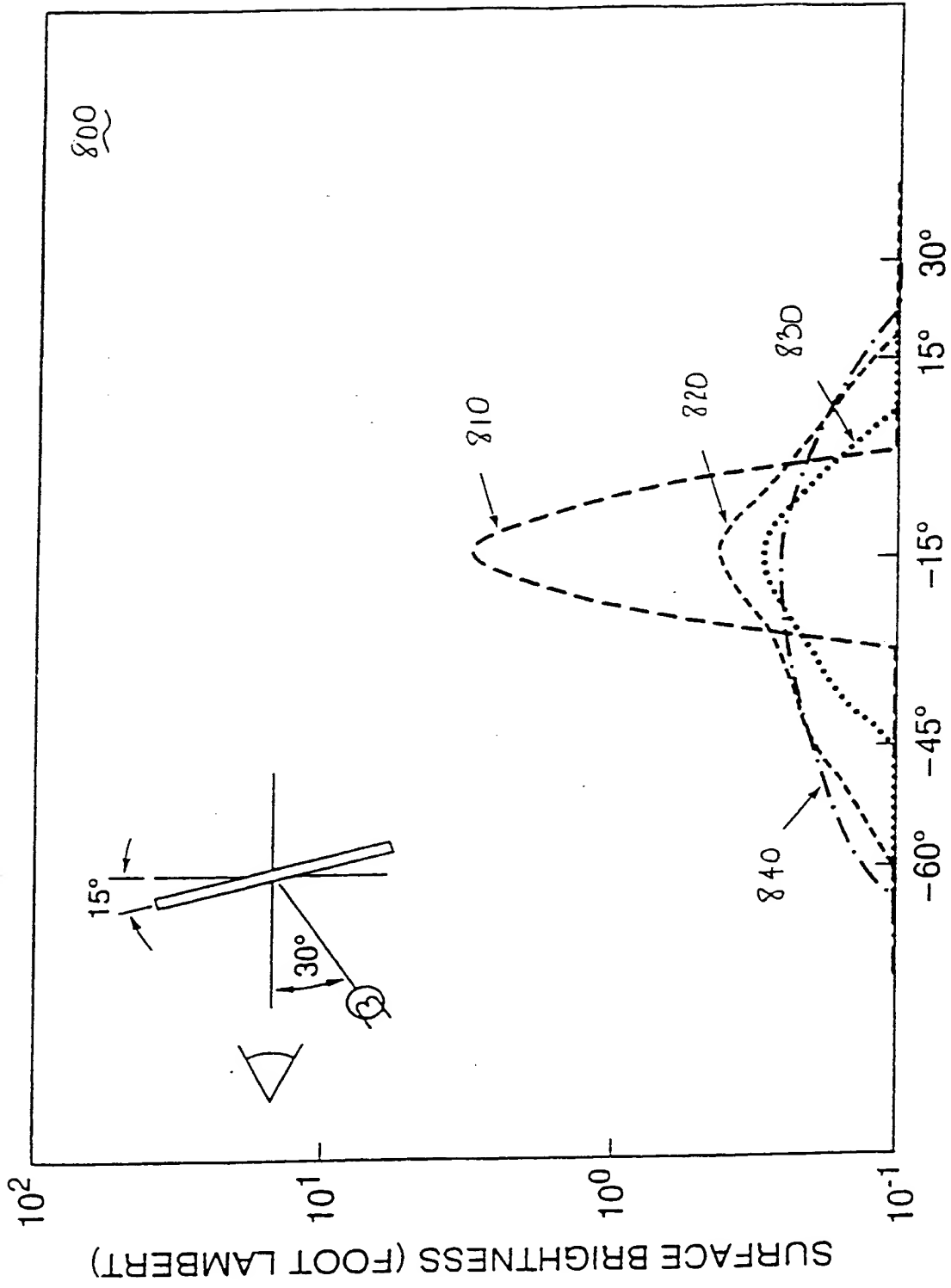


Figure 8



European Patent  
Office

## EUROPEAN SEARCH REPORT

Application Number  
EP 96 30 8822

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Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (Int.Cl.6)
X	EP 0 621 500 A (AT & T CORP) 26 October 1994 * column 4, line 14 - line 25 * * column 5, line 33 - line 54; figure 9 *	1,10	F21V8/00
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A	EP 0 571 173 A (NOKIA MOBILE PHONES LTD) 24 November 1993 * column 3, line 1 - line 19; figure 1 *	7,9	
A	FR 2 052 166 A (BARRIER) 9 April 1971 * figure 5 *	3,4	
The present search report has been drawn up for all claims			
Place of search THE HAGUE		Date of completion of the search 14 March 1997	Examiner Van Overbeeke, J
CATEGORY OF CITED DOCUMENTS X : particularly relevant if taken alone Y : particularly relevant if combined with another document of the same category A : technological background O : non-written disclosure P : intermediate document T : theory or principle underlying the invention E : earlier patent document, but published on, or after the filing date D : document cited in the application I : document cited for other reasons & : member of the same patent family, corresponding document			

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